INDEX

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Class EEE Section EM Roll No. 81 Year 2022

Subject EM LAB - B.TECH

Sl. No.	Experiment Description	Experiment Date	Submission Date	Remarks Signature
1.	Introduction to synchronous machines Experiment I	08-08-22	14-11-22	
2.	Introduction to asynchronous machines. Experiment II	08-08-22	14-11-22	
3.	Voltage Regulation of a 1-Φ Alternator by direct loading. Experiment III	22-08-22	14-11-22	
4.	No-load + blocked rotor test. Experiment IV	29-08-22	14-11-22	
5.	Open-circuit & short circuit test on an induction motor. Experiment V	12-09-22	14-11-22	
6.	Load test on a 3-Φ induction machine. Experiment VI	10-10-22	14-11-22	

Sl. No.	Experiment Description	Experiment Date	Submission Date	Remarks Signature
7.	Slip test of a synchronous machine. Experiment VII	05-11-22	14-11-22	
8.	Back-to-Back test on two 1-Φ alternator. Experiment IX	05-11-22	14-11-22	
9.	V-curve of a 3-Φ synchronous machine. Experiment VIII	07-11-22	14-11-22	
10.	Voltage regulation of an alternator by synchronous impedance method. Experiment X	07-11-22	14-11-22	
	Total Experiments = 10			
	Semester V			
	MO-2022			

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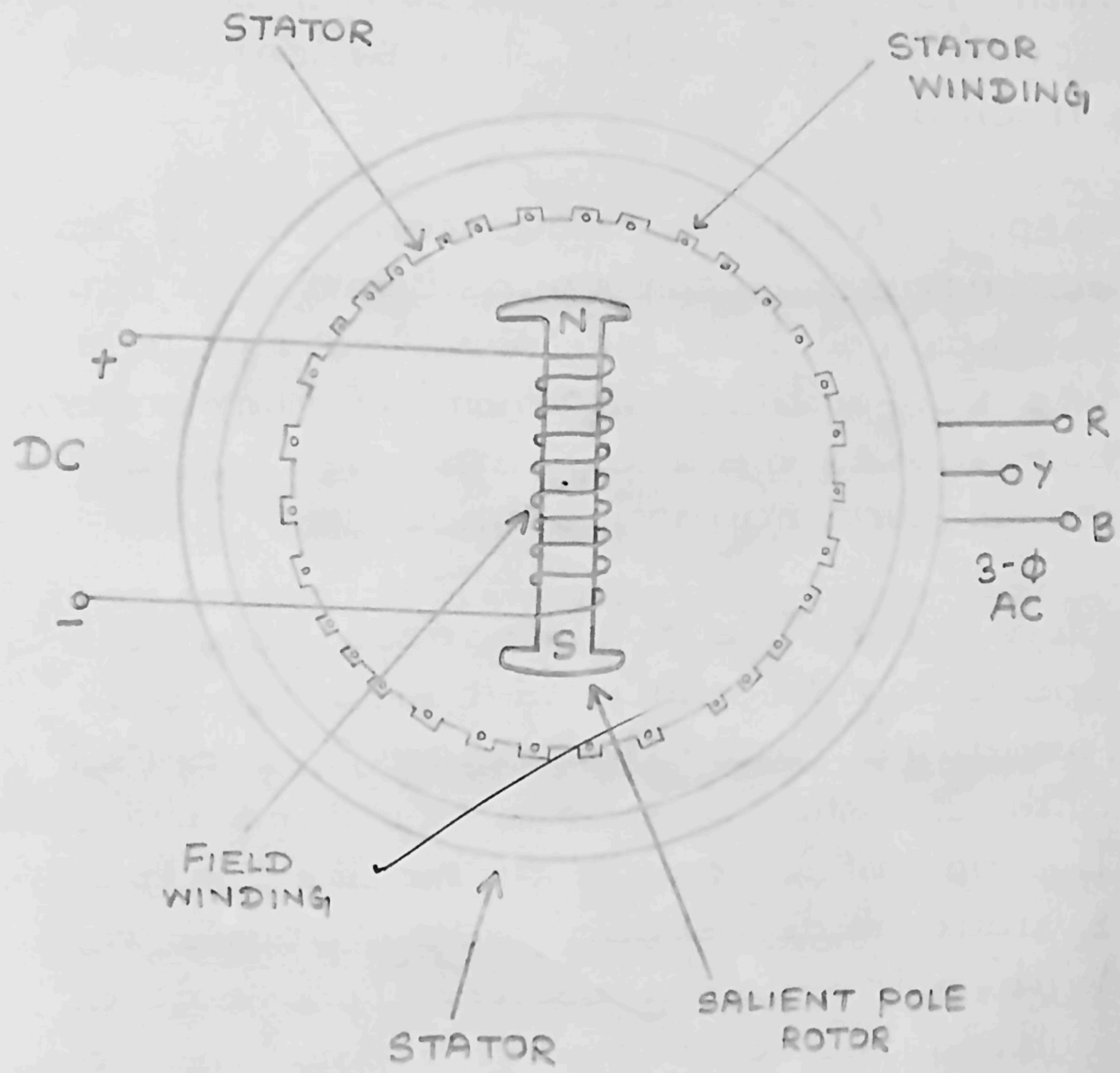
Experiment-1

Aim- To study the construction, types and operating principles of a synchronous machine.

Theory - A synchronous machine is an electromechanical transducer that converts mechanical into electrical energy and vice versa. The fundamental phenomena that makes these conversions possible is the electromagnetic induction.

Generator - The synchronous generator's operating principle is based on the faraday's law. The rotor is supplied with DC that produces a constant flux. The rotor is made to rotate at the synchronous speed using prime mover. With rotor the constant flux rotates cutting the stationary armature conductors in the slots. Thus an emf is produced and a current flows.

Teacher's Signature



SYNCHRONOUS MACHINE

Motor - The rotor is supplied with DC and produces constant flux ϕ and poles will devolop in rotor while stator is supplied $3-\phi$ AC. The three phase AC stator current produces rotating magnetic field that rotates at synchronous speed. The rotor also starts to rotate at synchronous speed.

Excitation Speed - Excitation of the synchronous machine means to excite the field winding of synchronous machine through DC supply. The field winding is placed on the rotor. The three main excitation systems are-

a. DC Excitation
b. Brushless Excitation
c. Static Excitation

Construction :

The Stationary part or Stator - Causes armature winding in which voltage is generated.

Yoke - The outer stationary cylindrical frame made of cast steel.

Stator Core - Magnetic core slotted to accomodate armature winding and made of 0.5 mm thick CRGO steel.

Armature Winding - The 3-ϕ armature winding are placed in slots of stator periphery. The armature winding is supplied by 3-ϕ AC.

The rotating part or rotor - It carries the field winding which is fed by DC Supply. The salient pole and cylindrical pole are the two types of rotor. The main difference is cyldrical rotor runs at higher speed (upto 3000 RPM) & field windings are distributed. The salient pole rotor runs at lower speed (upto 250 RPM) and field windings are concentrated.

Experiment - 2

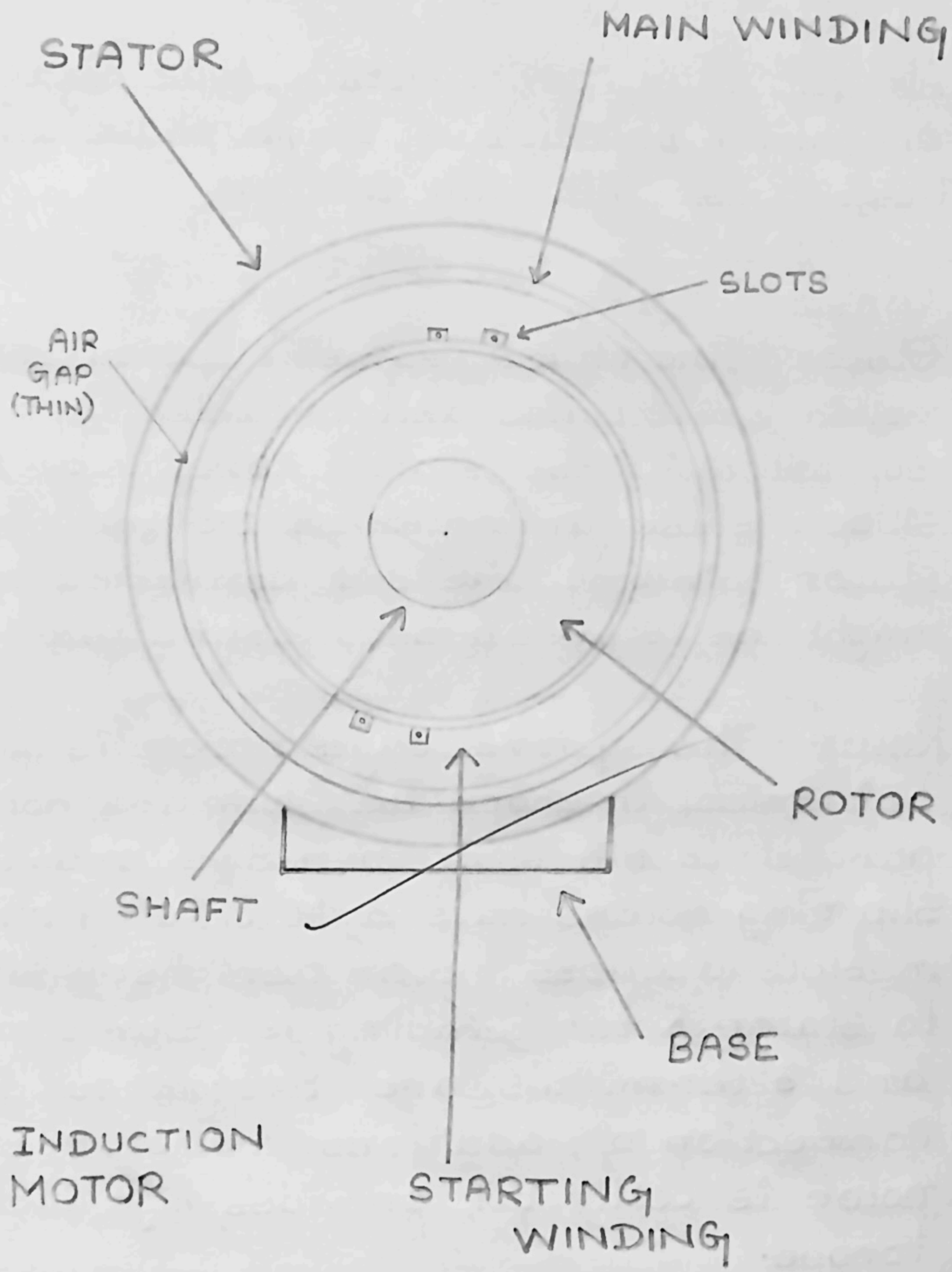
Aim - To study construction, type and the operating principle of single phase and a three phase induction motor.

Construction -

Stator - The stator frame is casted using rolled steel plates and provides mechanical support while the stator core is built by silicon steel lamination of 0.5 mm. The Stator winding are 3-ϕ connected and might be star or delta connected.

Rotor - The squirrel cage rotor is cheap & cylindrical in shape. The slots are not in parallel to the shaft to reduce crawling. Slip ring rotors have 3-ϕ winding placed in slots accross rotor periphery similar to stator. Rotor winding is star connected and 3 terminals are brought out for the connection of additional resistance. The rotor is costly but provides high starting torque.

D-I



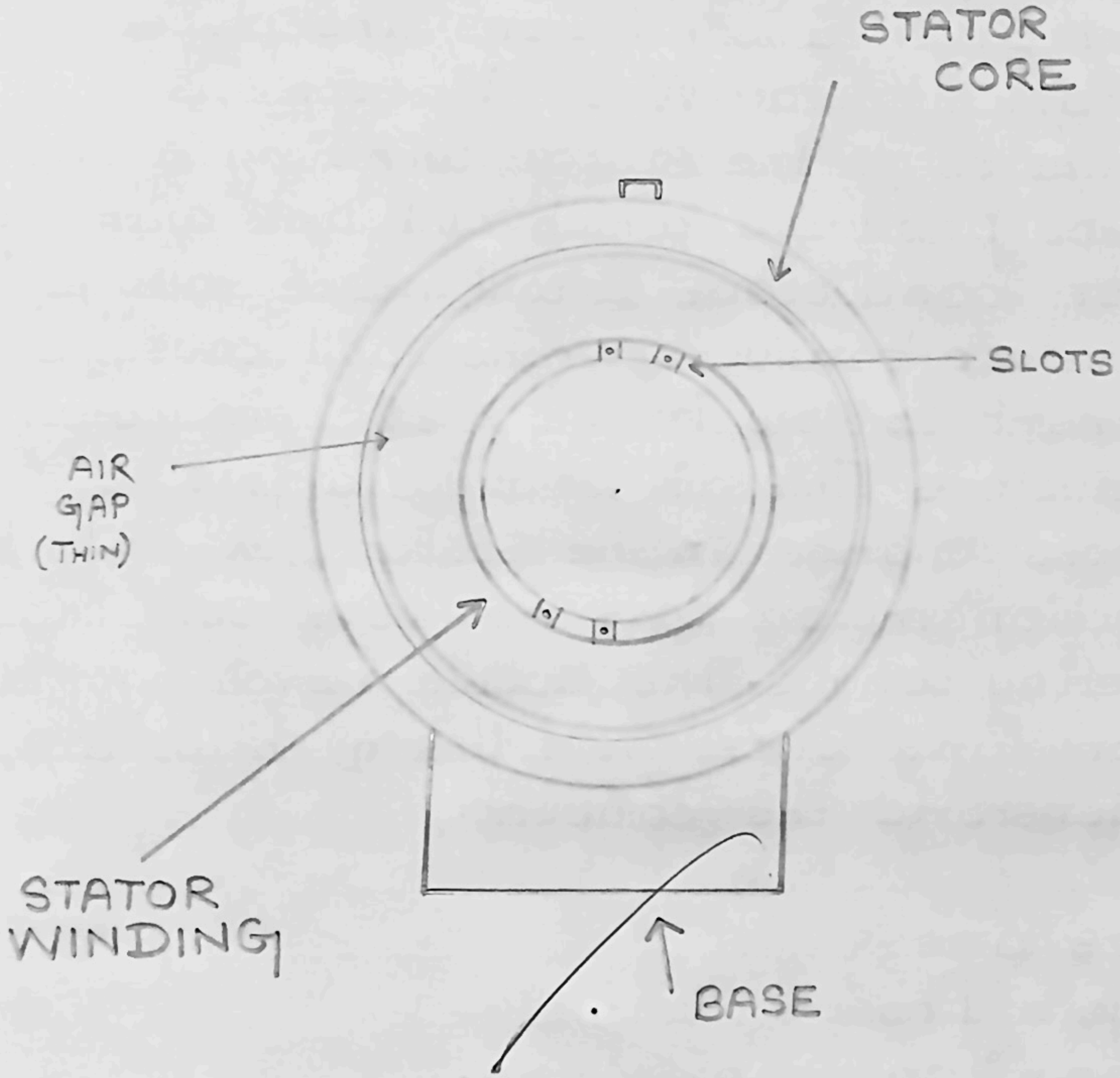
1-Φ INDUCTION MOTOR

Single Phase Induction Motor -

It is similar to 3-Φ induction motor. The stator has single phase AC Windings while short circuited conductors are placed in a cylindrical rotor. When AC supply is connected to the stator winding a flux will be produced which will link with the rotor conductors. It will induce voltage in the rotor conductors. That will cause a current to flow in the short-circulated conductors. This will produce a flux to oppose change in the stator flux. 1-Φ induction motor does not have self starting torque. The double revolting field theory and cross field theory helps to understand the concept.

Types are -
1. Split-Phase Motor.
2. Capacitor Start Motor.
3. Shaded Pole Motor.
4. Capacitor Start & Run Motor.

E - II



3-Φ INDUCTION MOTOR

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3-Φ Induction motor -

Three phase stator current produces a rotating magnetic field in the air gap. The rotating magnetic field cuts the rotor conductor and as emf will be induced the rotor will start rotating. When the rotor speed becomes equal to the synchronous speed, the flux cutting between RHF and rotor will stop and induced emf in rotor conductors will become zero. Thus an induction motor can never rotate at synchronous speed.

Teacher's Signature

Experiment - 3

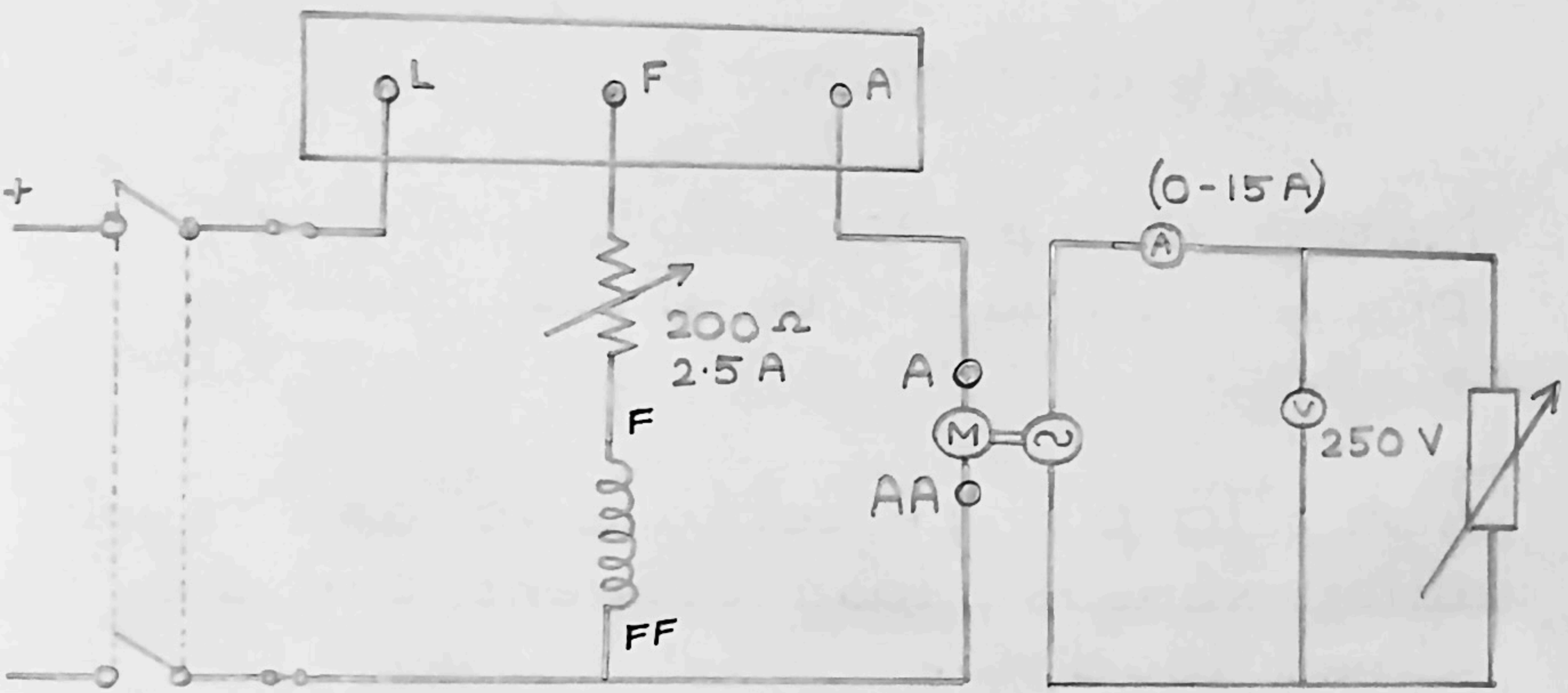
Name- Voltage regulation of a single phase alternator by direct loading method.

Aim - To plot percentage voltage regulation versus load current curve by direct loading.

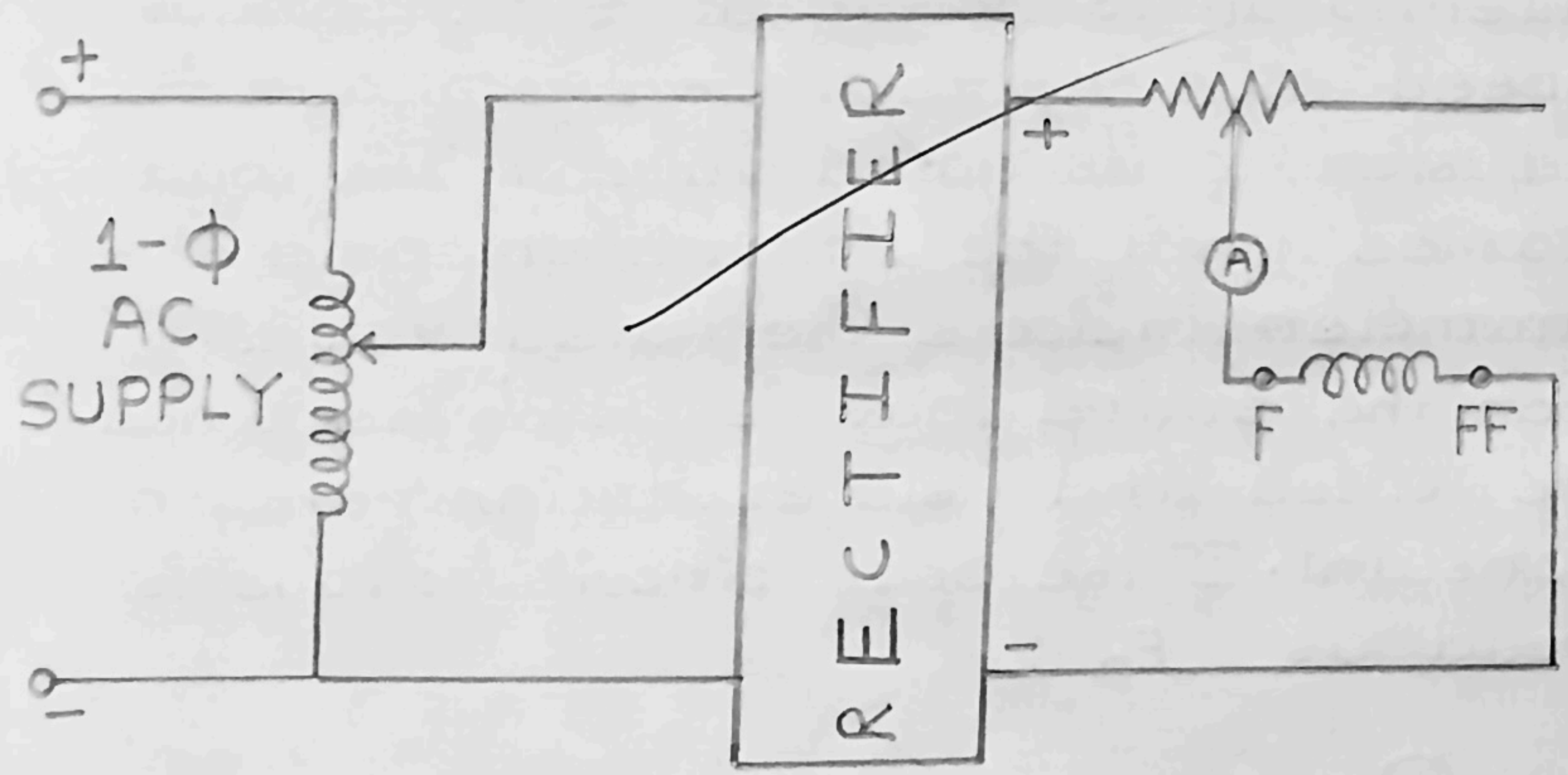
Theory - In direct loading method the alternator is driven at synchronous speed and the terminal voltage is adjusted to its rated value V. The load is varied until the voltmeter and the ammeter indicate the rated values. Then the entire load is removed while the speed and field excitation remain constant. If the open circuit voltage is read as E_0,

$$\% \text{ Regulation} = E_0 - V / V \times 100$$

D-I



CIRCUIT DIAGRAM



D-II

Specification of Machine-

DC Shunt Motor:

230 V, 20 A

1500 RPM

HP = 3

Single Phase Alternator:

3 KVA, 50 Hz

230 V, 13 A

cos ϕ = 0·8

1500 RPM

Apparatus Required:

AC Voltmeter (0-250 V) - 1 nos.

AC Ammeter (0-15 A) - 1 nos.

DC Ammeter (0-1 A) - 1 nos.

Rheostat (290 Ω, 1.5 A) - 2 nos.

Rectifier - 1 nos.

Auto-Transformer - 1 nos.

Lamp load (200 W, 250 V)

Tachometer - 1 nos.

OBSERVATION TABLE

SL	LOAD	VOLT.	CURRE. Multiplied by 2 values:	VOLT REGULA.
1	200W	190V	1 A	0 %
2	400W	180V	1.6 A	5.263%
3	600W	165V	2.4 A	13.157%
4	800W	150V	2.8 A	21.052%
5	1000W	144V	3.6 A	24.210%
6	1400	118V	4.4 A	37.894%

At LOAD-

SL	LOAD	VOLT.	FIELD CURRENT
1	0 W	230V	0.75 A
2	0 W	230V	0.75 A
3	0 W	230V	0.75 A
4	0 W	230V	0.75 A
5	0 W	230V	0.75 A
6	0 W	230V	0.75 A

AT NO LOAD-

$$V.R = E - V_t / V_t \times 100\%$$

Procedure:

Make the connection as per the diagram and while Keeping the DC motor field rheostat in minimum resistance position start the DC motor with the help of the starter and adjust the motor speed to synchronous speed with the help of motor field rheostat. Load the alternator to its rated current maintaining rated voltage and synchronous speed. Note no-load voltage after adjusting the speed and field excitation to its rated value.

Precautions:

Before starting DC Shunt Motor set the field rheostat to its minimum resistance value position. DC motor must be Started using a starter. Maintain the Synchronous speed throughout the experiment.

Result:

Voltage Regulation is between 5.263 to 37.894% for this machine.

Teacher's Signature ....

Experiment-3

Voltage Regulation:
Graph

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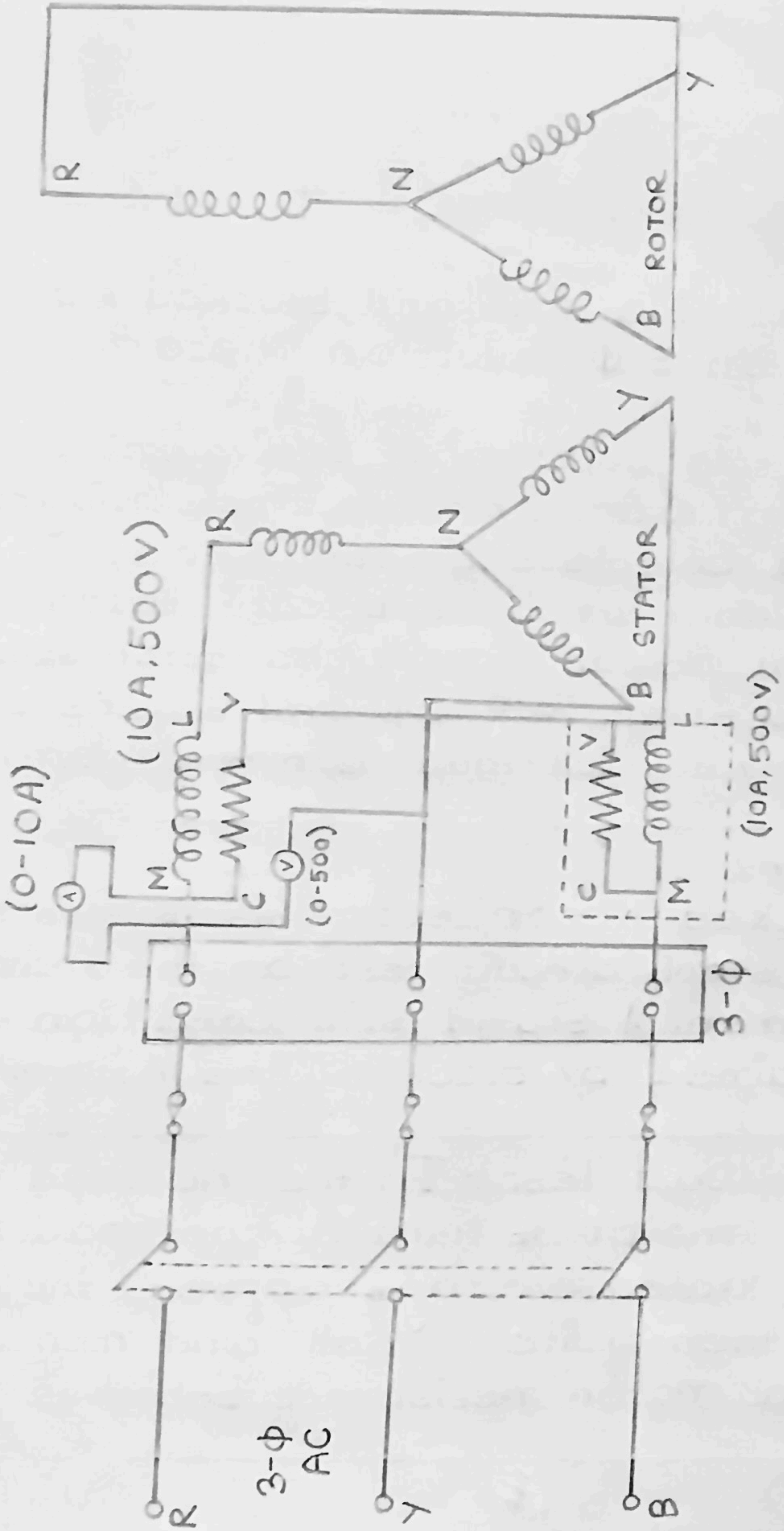
Experiment-4

Name - No load and blocked rotor test on 3-ϕ induction motor.

Aim - To determine equivalent circuit parameters, draw circle diagram and calculate power factor, efficiency and slip at full load. To draw performance charecteristics of percent η, BHP, p.f and S versus normal full-load current curves.

Theory -
Blocked Rotor Test - This is similar to the short circuit test on the trans-former. A stand still condition is obtained by blocking the rotor.

No-load Test - In the no-load test the motor is run at no-load with the rated voltage applied, the slip is then quite small and hence total rotor resistance becomes large.



NO LOAD + BLOCKED ROTOR TEST (3-Φ IM)

Thus the blocked rotor test is also called the short-circuit test & no-load test is also called open-circuit test.

Machine Specifications
Stator - 400/440 V, 5.5 A
1500 RPM, 50 Hz
BHP = 3
Rotor = 300 V, 5.2 A
Winding Y

Apparatus Required :
1. 3-Φ Auto-transformer
2. AC Ammeter (0-10 A)
3. AC Voltmeter (0-500 V)
4. AC Voltmeter (0-300 V)
5. Wattmeter (10 A, 500 V)

Procedure-
a. For blocked rotor test :
Make connections as per circuit diagram and set the autotransformer to zero output and switch on 3-Φ AC supply. Start the motor by applying the

CALCULATIONS-

$$V.R = E_f - V_t / V_t \times 100$$

1. $V.R = 190 \; 180/180 = 5.26\%$
2. $V.R = 190 - 165/165 = 13.31\%$
3. $V.R = 190 - 150/150 = 21\%$
4. $V.R = 190 - 144/144 = 24.2\%$
5. $V.R = 190 - 118/118 = 37.8\%$

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voltage gradually with initially a low voltage so that stator current does not exceed rated value. At rated stator current, note observations.

For no load test - Set autotransformer to zero output and switch on 3-ϕ AC supply. Start the motor by applying the voltage gradually and go upto rated rated value and note down readings.

SL	INPUT LINE V	INPUT LINE I	W_1	W_2	$W_1 + W_2$	RPM
1	160 V	0.5 A	50 W	60 W	110 W	1050
2	200 V	0.9 A	60 W	70 W	130 W	1200
3	240 V	1.5 A	70 W	80 W	150 W	1425
4	300 V	2 A	80 W	90 W	170 W	1480
5	340 V	2 A	85 W	95 W	180 W	1505
6	400 V	2.5 A	90 W	100 W	190 W	1560
7	440 V	3.3 A	100 W	110 W	210 W	1600

SL	INPUT LINE V	INPUT LINE I	W_1	W_2	$W_1 + W_2$
1	140 V	5.5 A	720 W	100 W	820 W

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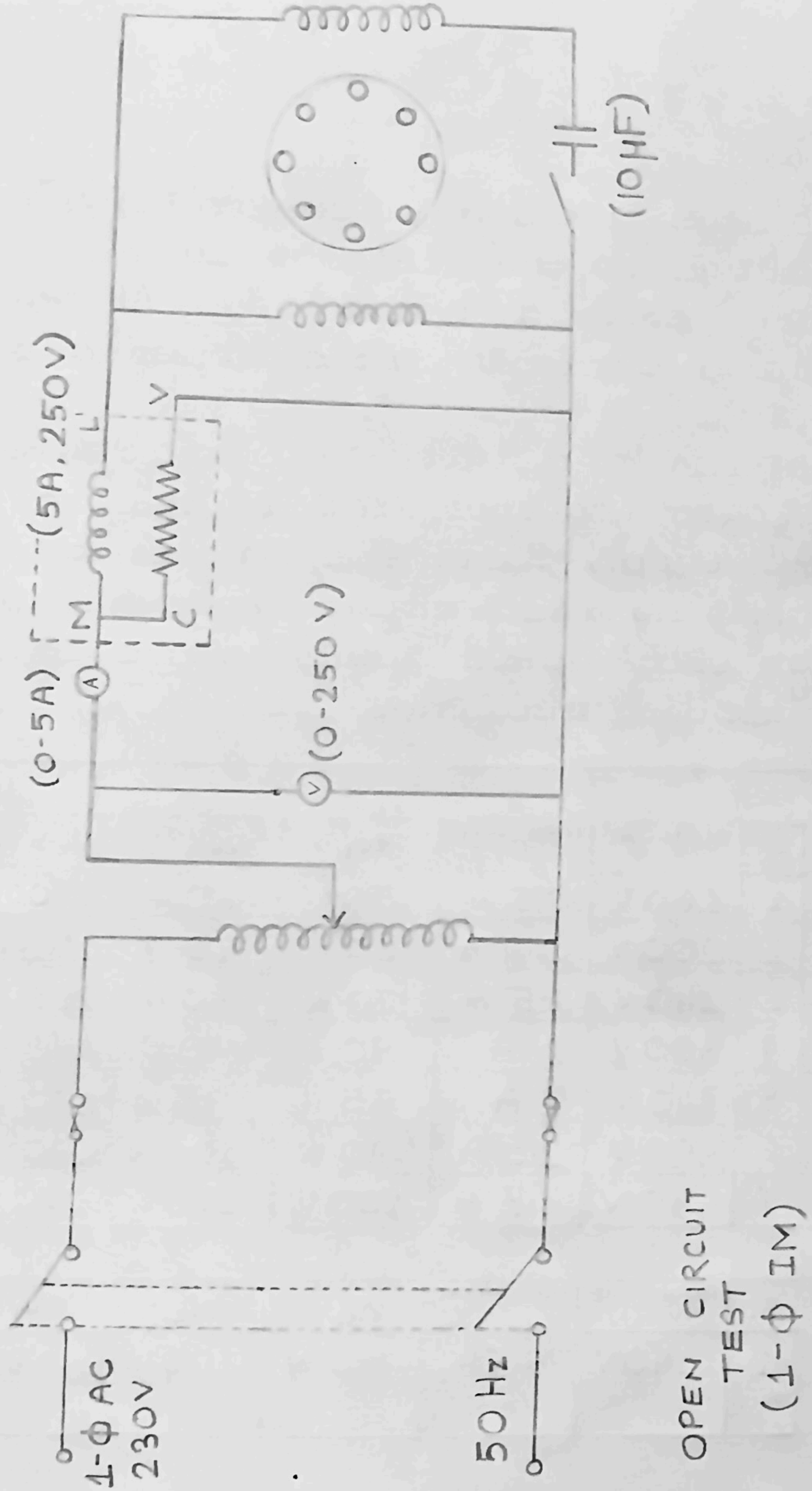


Experiment - 5

Name - Open & Short Circuit test on a 1-Φ Induction motor.

Aim - To study -

a. The 1-Φ Induction motor does not devolop any starting torque without auxillary winding.

b. The starting torque in a 1-Φ Induction motor is devoloped by connecting capacitor either in main or auxillary windings.

c. To determine losses & equivalent circuit parameters.

d. Draw circuit diagram & determine the performance charecteristics of the test machine.

Precautions -

a. Open - Circuit test should be performed at rated voltage.

b. Short - circuit test should be performed at rated current.

SL	INPUT V	INPUT I	INPUT POWER	SPEED
1	10 V	1.2 A	20 W	0 RPM
2	19 V	1.6 A	25 W	0 RPM
3	30 V	2.2 A	50 W	0 RPM
4	50 V	4.4 A	120 W	0 RPM

SHORT-CIRCUIT TEST (1-Φ IM)

Machine Specifications-

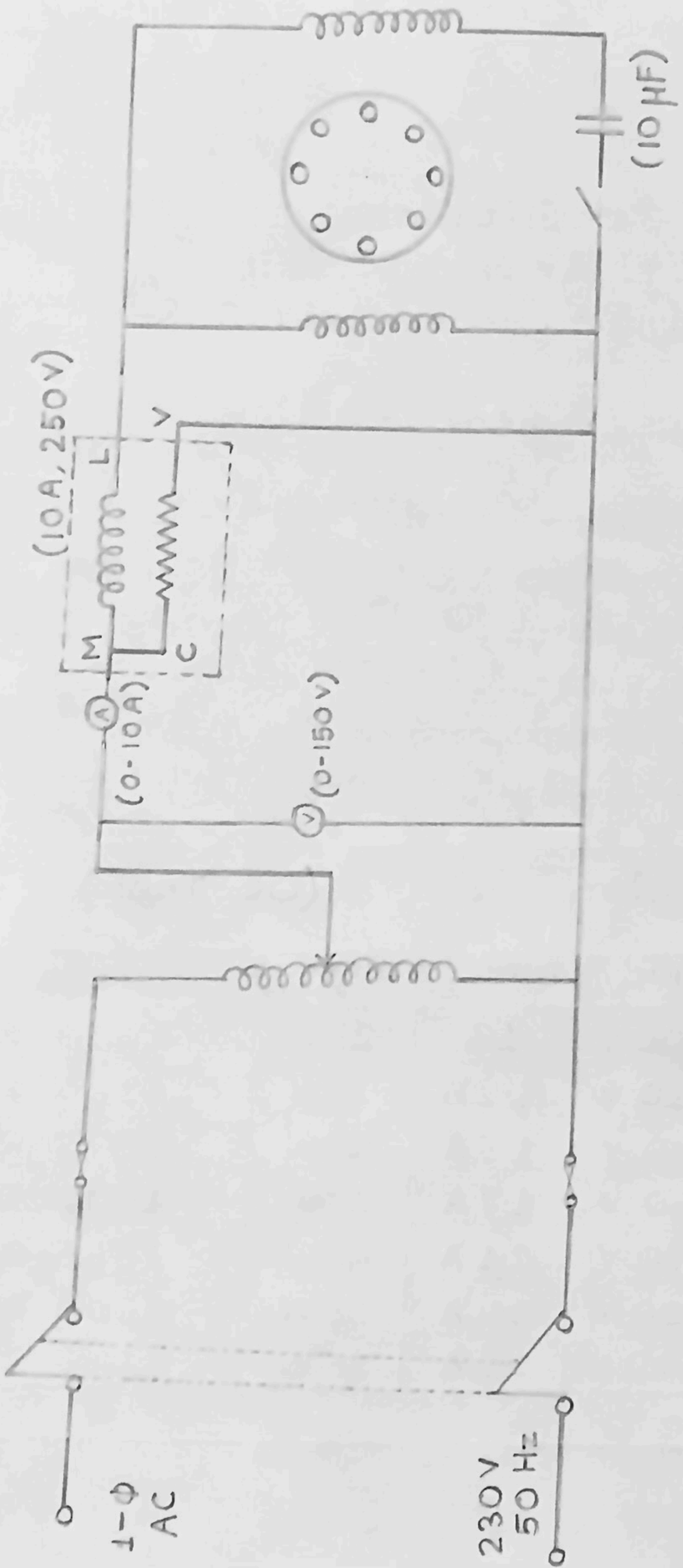
230 V, 540 Amps, 1.5 BHP
1-Φ Induction motor, 1420 RPM

Apparatus Required-

AC Voltmeter (0-250V) - 1 nos.
AC Wattmeter (5A, 300 V) - 1 nos.
AC Ammeter (0-5 A) - 1 nos.
AC Ammeter (0-10 A) - 1 nos.
1-Φ Auto-Transformer (10 A, 300 V) - 1 nos.
Capacitor (10 μF) - 1 nos.

Observation Table - (OC-Test)

SL	INPUT V.	INPUT I.	INPUT POWER	SPEED
1	100 V	1 A	25 W	1050 RPM
2	120 V	1.2 A	25 W	1260 RPM
3	140 V	1.5 A	25 W	1375 RPM
4	160 V	1.7 A	27 W	1500 RPM
5	180 V	2.1 A	40 W	1565 RPM
6	200 V	2.4 A	55 W	1600 RPM
7	220 V	2.7 A	75 W	1665 RPM



SHORT CIRCUIT TEST (1-φ IM)

Calculations:

Stator winding resistance = 2.5 Ω

For SC -

$V = 220$ V

$I = 2.7$ A

$W = 120$ W

$$Z_{sc} = \sqrt{R^2 + X^2}$$

$$Z_{sc} = V/I = 220/2.7 = 81.481\ \Omega$$

$$R_{sc} = \omega_{sc}/I_{sc}^2 = 120/(2.7)^2 = 16.460\ \Omega$$

now,

$$X_{sc} = \sqrt{(Z_{sc})^2 - (R_{sc})^2} = \sqrt{(81.481)^2 - (16.46)^2}$$

$$= 79.801\ \Omega$$

or 80 Ω (Approximately)

Experiment - 6

Name - Load test on 3-ϕ induction motor

AIM - To obtain load charecteristics of a 3-ϕ induction motor :

A. Percent Speed
B. BHP
C. Efficiency
D. Torque
E. Power Factor
F. Slip Vs Percent normal full load current

THEORY - We know that as the induction motor is loaded the speed drops down the current increases & the power factor is improved. The purpose of the load test is to study the behaviour of an induction motor under load.
Suppose the motor is running on no load. The slip is small and a very small no load current flows. As the mechanical

load on the motor is increased, the speed drops due to its retarding effect, the current & the rotor power output increases. Thus the motor adjusts itself to the new load conditions of an increased output corresponding to which the input current also increases and the speed drops.
At the light load, the power factor is lagging and the under rated load is lagging but improves. The BHP is given by the relation → BHP = WN/500, where W is the spring balance reading (lb) & N is the speed (RPM).

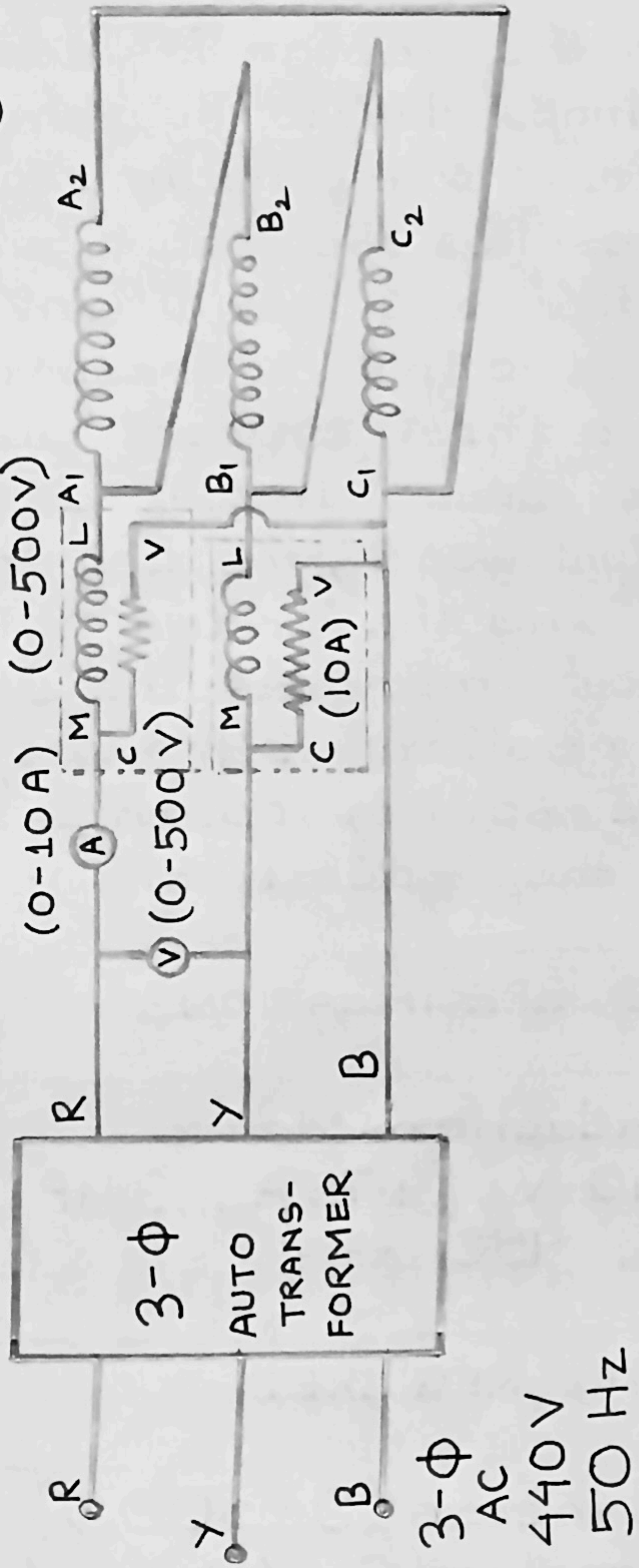
MACHINE SPECIFICATIONS –

3-ϕ Induction Motor
400/440 V, 4.75 A, 3 HP
50 Hz, 950 RPM

APPARATUS REQUIRED –

AC Voltmeter (0-500 V) - 1 NOS.
AC Ammeter (0-10 A) - 1 NOS.
Wattmeter (10 A, 500 V) - 2 NOS. and

CIRCUIT (E/3)
DIAGRAM



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Calculations-

$Efficiency_1$ = O/P power / I/P power x 100 % = 0/360 x 100
$Efficiency_2$ = 145.95/368 x 100 = 39.66 %
$Efficiency_3$ = 432.28/1048 x 100 = 41.24 %
$Efficiency_4$ = 1000.48/1472 x 100 = 67.96 %
$Efficiency_5$ = 1278.59/1892 x 100 = 68 %
$Efficiency_6$ = 1958.05/2420 x 100 = 80.91 %
$Efficiency_7$ = 2223.53/2720 x 100 = 81.74 %

BHP_1 = $P_{o/p}$ x 746 = 0 x 746 = 0
BHP_2 = 145.95 x 746 = 10964.7
BHP_3 = 432.28 x 746 = 322480.88
BHP_4 = 1000.48 x 746 = 746358.08
BHP_5 = 1278.59 x 746 = 953828.14
BHP_6 = 1958.53 x 746 = 1460705.3

OXFORD

Teacher's Signature

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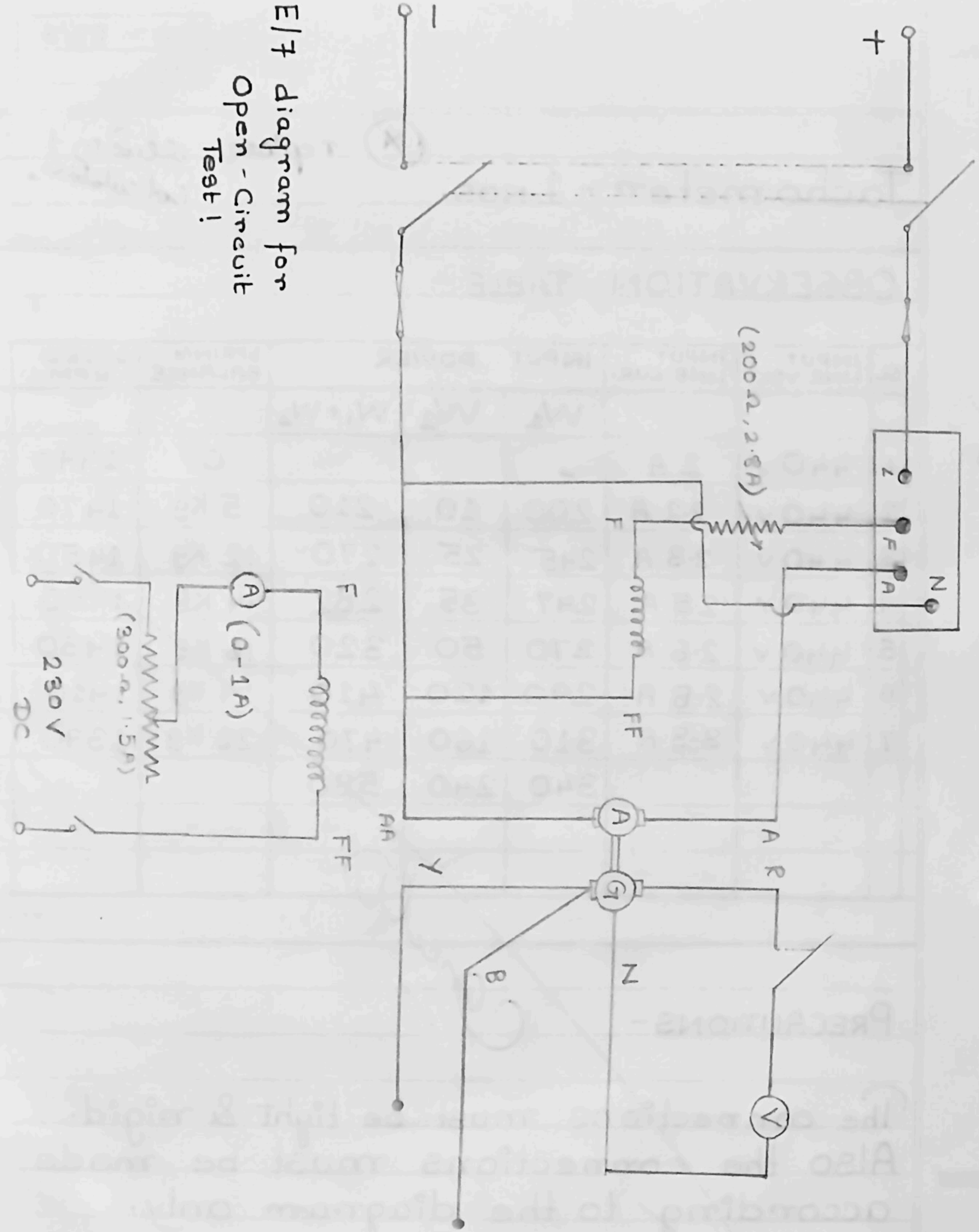
Observation Table:

SL	Input V.	Input I	Watt meter	watt meter	Total I/P Power	Spring Balance	RPM	Slip(S)	τ	Power Factor	O/P power	η
1	440	2	30	60	360	0	1499	0·066	0	0·856	0	0
2	440	2·05	30	62	368	1	1497	0·2	0·931	0·856	145·9	39·66
3	440	2·1	115	147	1048	3	1478	1·47	2·793	0·97	432·8	41·24
4	440	2·5	168	200	1472	7	1466	2·26	6·517	0·98	1000	67·96
5	440	2·8	218	255	1892	9	1457	2·87	8·38	0·99	1278	68
6	440	3·3	280	325	2420	14	1435	4·33	13·03	0·991	1958	80
7	440	3·6	312	360	2720	16	1426	4·93	14·89	0·992	2223	81·74

Teacher's Signature ....

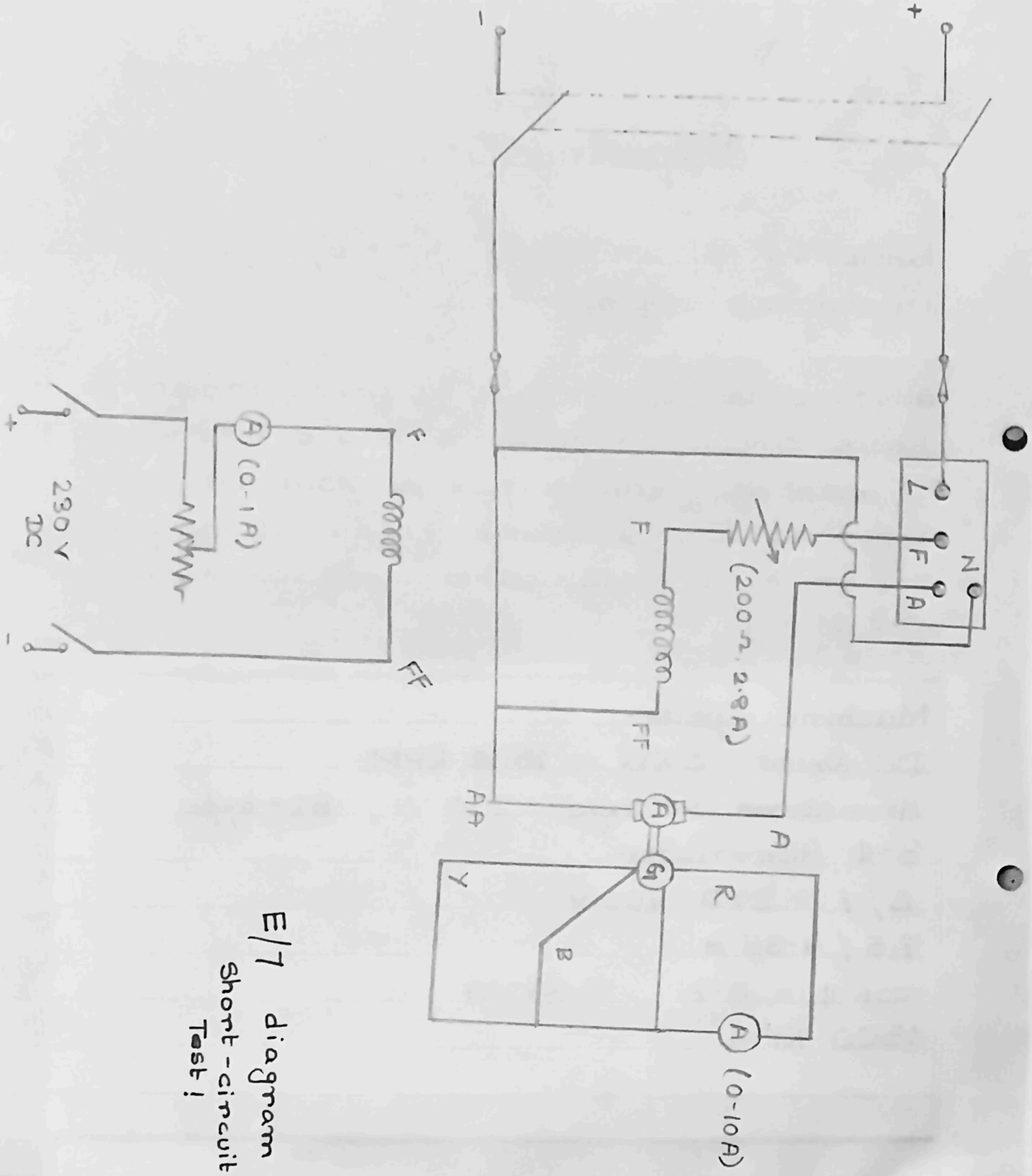


Experiment-7

NAME - V.R of an alternator by synchronous impedance method.

AIM - Plot the o/c voltage vs field current, short circuit current vs field current, synchronous impedance vs field current, % V.R vs load current graphs & the phasor diagram at rated armature current for 0.8 pf lag.

Experiment-7 Graph:



E/T diagram for Short-circuit Test:

Apparatus Required :

Double Barrel Rheostat

DC Ammeter (0-1 A)

AC Voltmeter (0-300 V)

AC Ammeter (0-10 A)

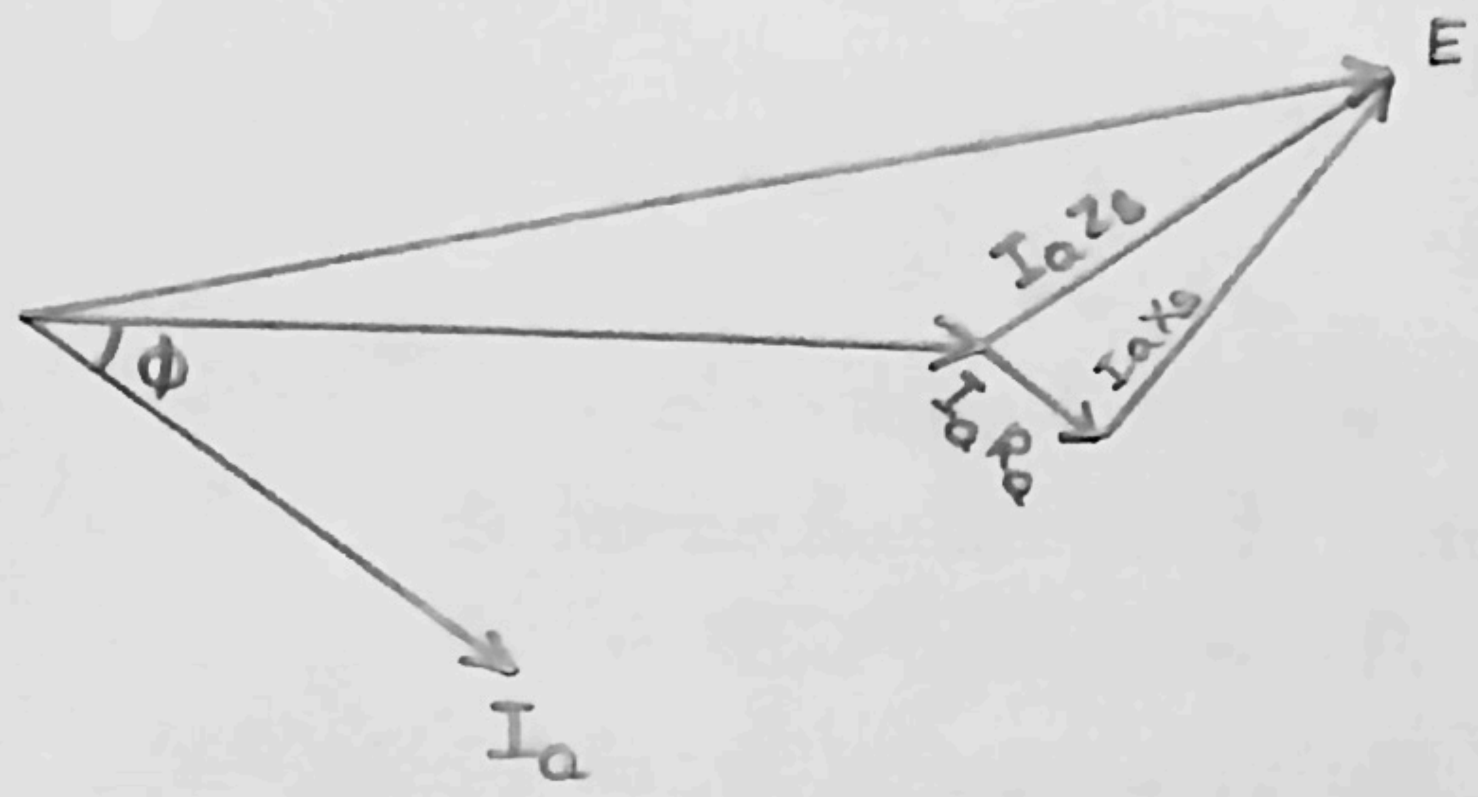
Tachometer

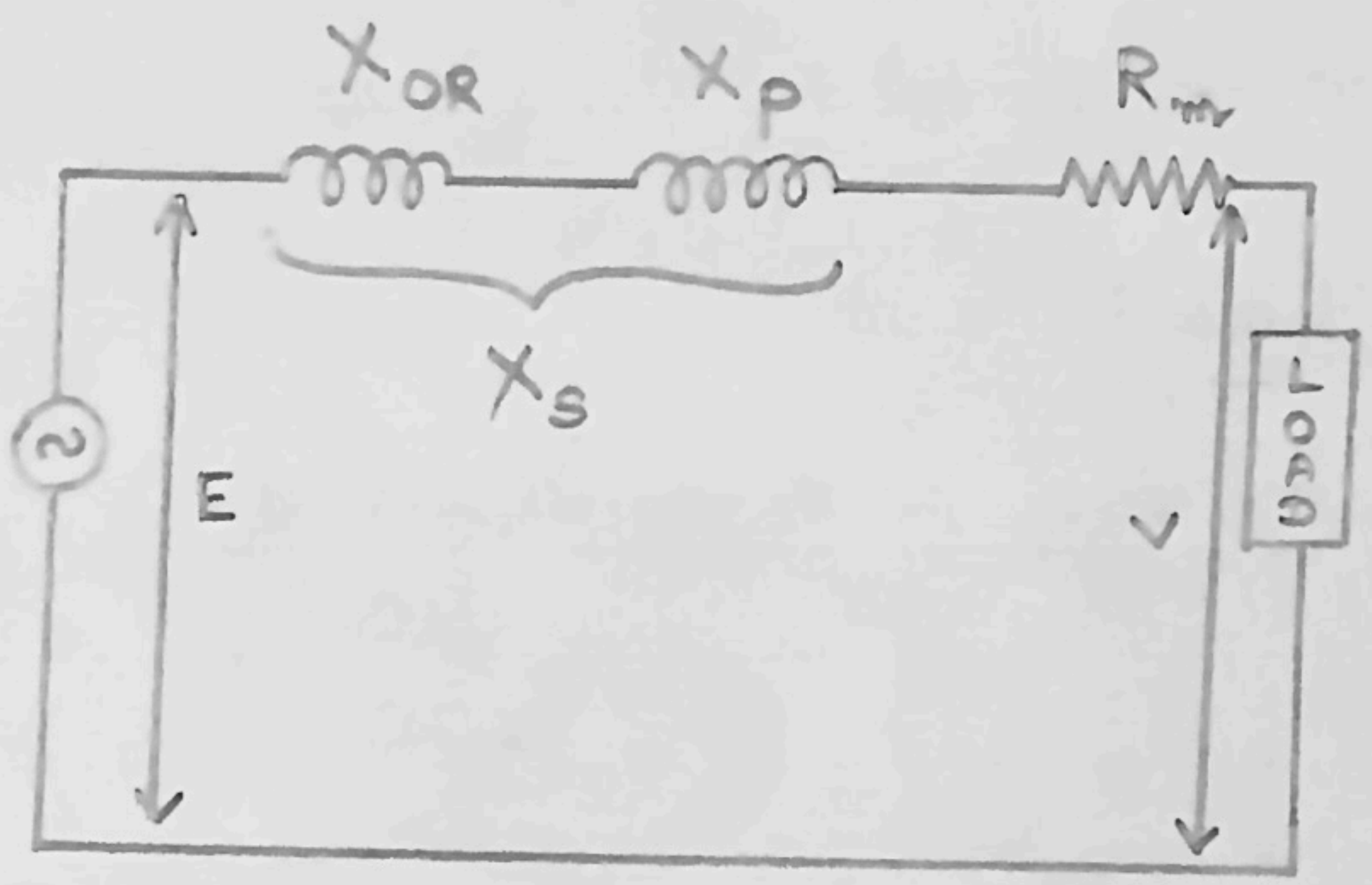
Rheostat (300 Ω, 1.5 A)

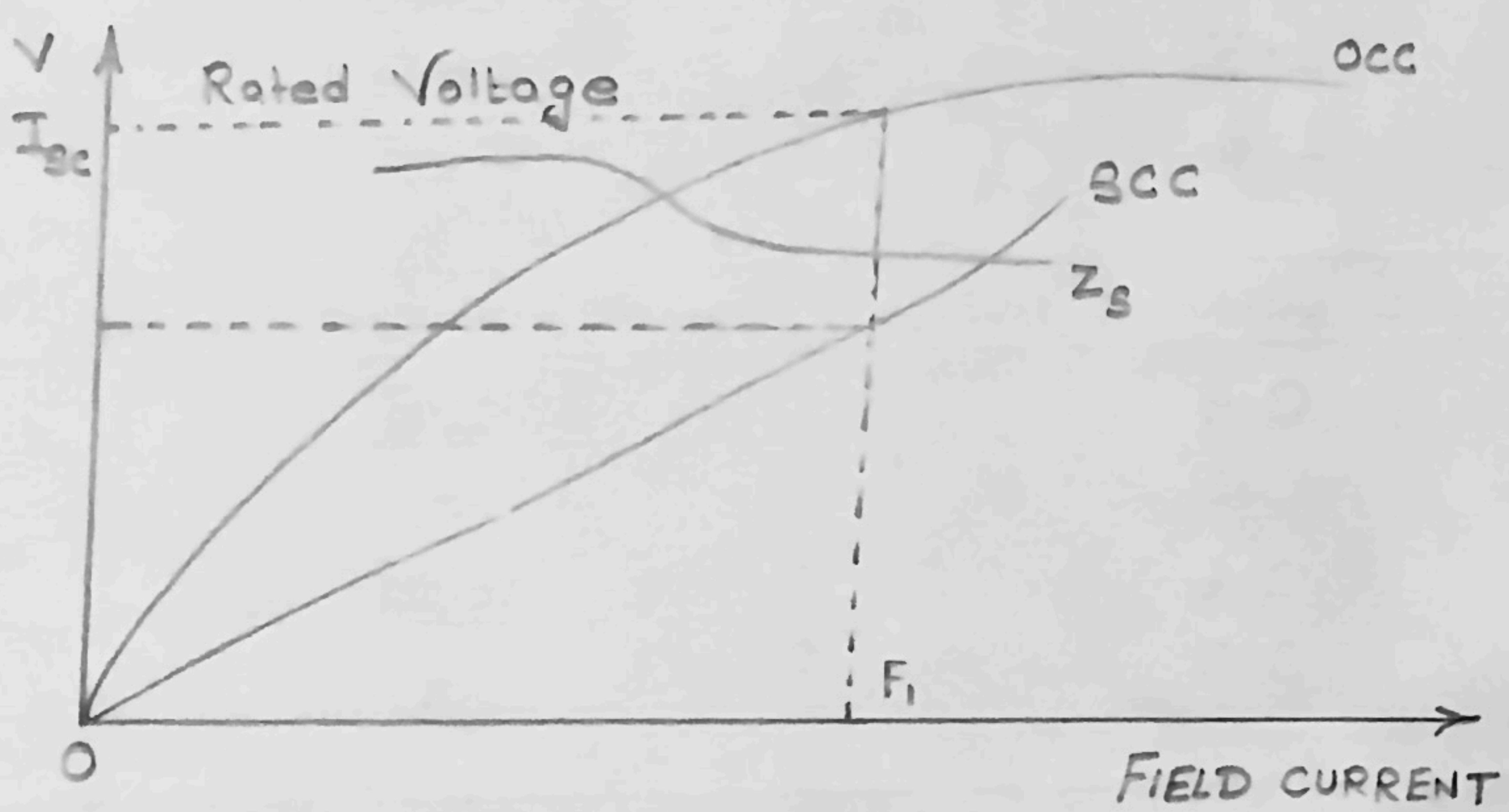
Observation Table :

SL	FIELD CURRENT (O/C)	Terminal Voltage (O/C)
1	0.4	90
2	0.5	100
3	0.6	120
4	0.75	140
5	0.9	160
6	1.5	180
7	1.8	200

SL	FIELD CURRENT (S/C)	Short-circuit Current
1	0.4	2.5
2	0.5	3
3	0.6	3.5
4	0.7	4







Calculations-

$$Z_s = 140/4 = 35$$

$$r_a = 5.2\,\Omega$$

$$X_s = \sqrt{Z_s^2 - r_a^2}$$

Also,

$$\vec{E_f} = \vec{V_t} + \vec{I_a r_a} + j\vec{I_a X_s}$$

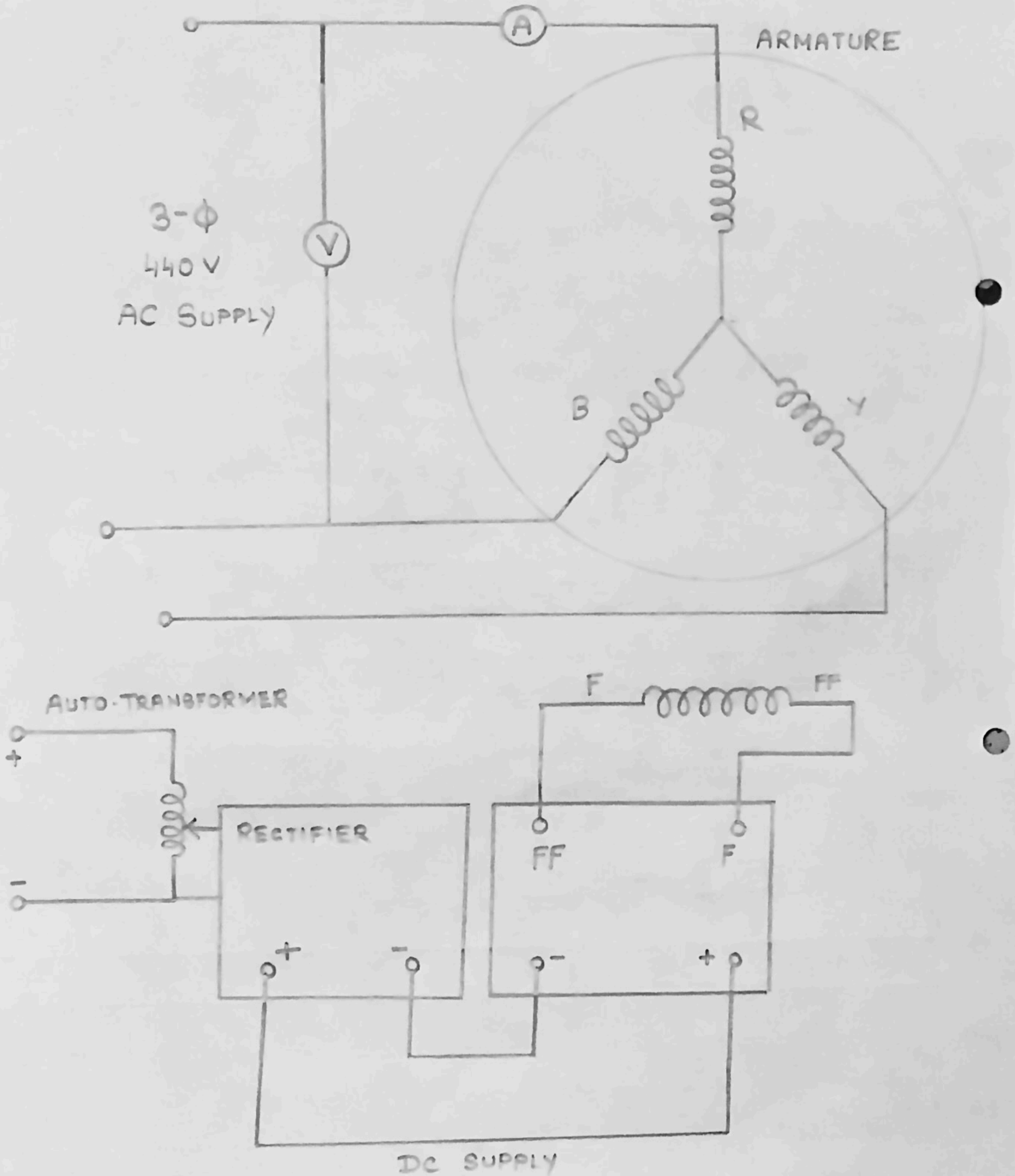
$$\therefore X_s = \sqrt{35^2 - (5.2)^2}$$

$$= \sqrt{1225 - 27.04}$$

$$= \sqrt{27.04}$$

$$= 5.2\,\Omega$$

E/8



Experiment - 8

NAME - V-curve of a 3-ϕ synchronous motor.

AIM - To draw the armature current vs field current curves for no load, half-load & full load & draw the unity p.f. line on the curves.

THEORY - The synchronous motor has the property of power factor varying with excitation. P.f. can be controlled by varying I_f.

Procedure -

Make connections as per diagram & switch on the machine with rated voltage & knife switch at position 1. Change the knife switch with position 2. With no load on motor, vary the motor field current.

Apparatus Required -

AC Ammeter (0-10A)
DC Ammeter (0-5A)
AC Voltmeter (0-500V)
Rectifier
Knife Switch

OBSERVATION TABLE

SL.	FIELD CURRENT (A) → [I_f]	Armature Current [I_a]
1.	0 A	9.5 A
2.	0.42 A	6.5 A
3.	0.61 A	5.5 A
4.	0.71 A	4.5 A
5.	0.90 A	3.4 A
6.	1.3 A	2 A
7.	1.37 A	1 A

Experiment - 8
Graph:

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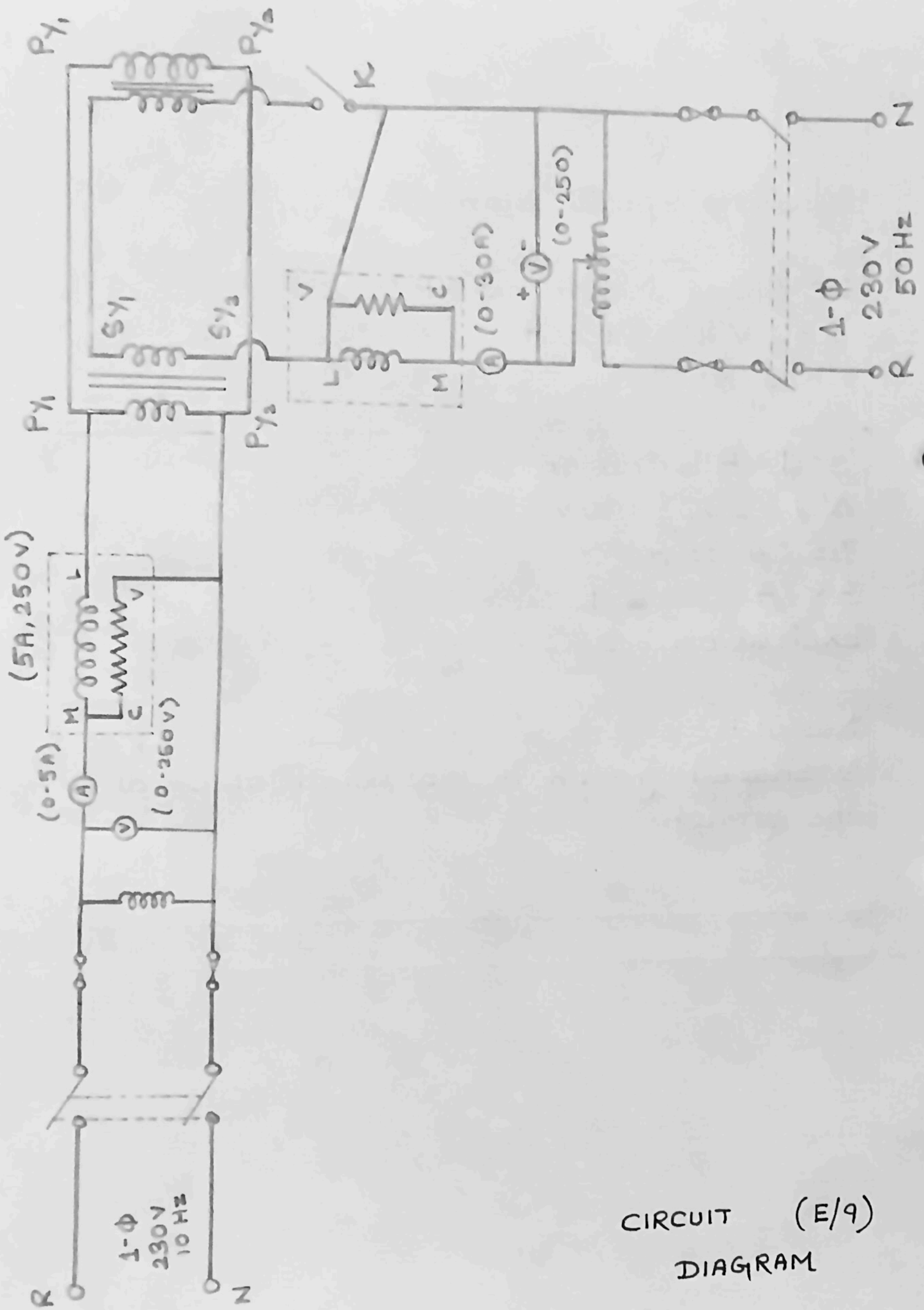
Machine Specifications-

DC Shunt Motor - 5 HP
230 V , 19.3 A
1500 RPM

3-ϕ Alternator
Δ/Y - 230/400 V
7.5 / 4.35 A
3 KVA , cos ϕ = 0.8
Excitation - 230 V

Result:
V-shaped graph is obtained after plotting the graph.



CIRCUIT (E/9)
DIAGRAM

Experiment - 9

NAME - Back-to-Back test on two 1-Φ transformer

AIM - To determine the iron loss, full load copper loss, equivalent circuit parameters. Draw percentage η vs load for 0.8 lag & lead.

Theory - The test provides us data to calculate regulation, η & heating is done when 2 similar transformers are available.

Procedure - Set auto-transformers to zero voltage output & connect secondaries in phase opposition. Connect terminals Sy_1 & Sy_2 together keeping switch K open. After checking phase opposition connect them to a low voltage supply. Supply rated voltage V_1. Adjust the secondary injected voltage to the required value until I_2 is equal to secondary current.
Note voltage, current & power of both the sides.

CALCULATIONS :

Core loss of both Transformers → 110 W

Core loss of 1 Transformer = 110/2 = 55W

Ohmic loss of both Transformer = 50 W

Ohmic loss of 1 Transformer = 50/2 = 25 W

$$\eta = \frac{O/P}{O/P + loss} \times 100\%$$

$$= \frac{1\times10^3}{1\times10^3 + 55 + 22} \times 100\%$$

$$= 92.59\%$$

MACHINE SPECIFICATIONS-

3 KVA , Single - Phase
50 Hz
Primary 230 V , 13.2 A
Secondary 115 V , 26.1 A

APPARATUS REQUIRED-

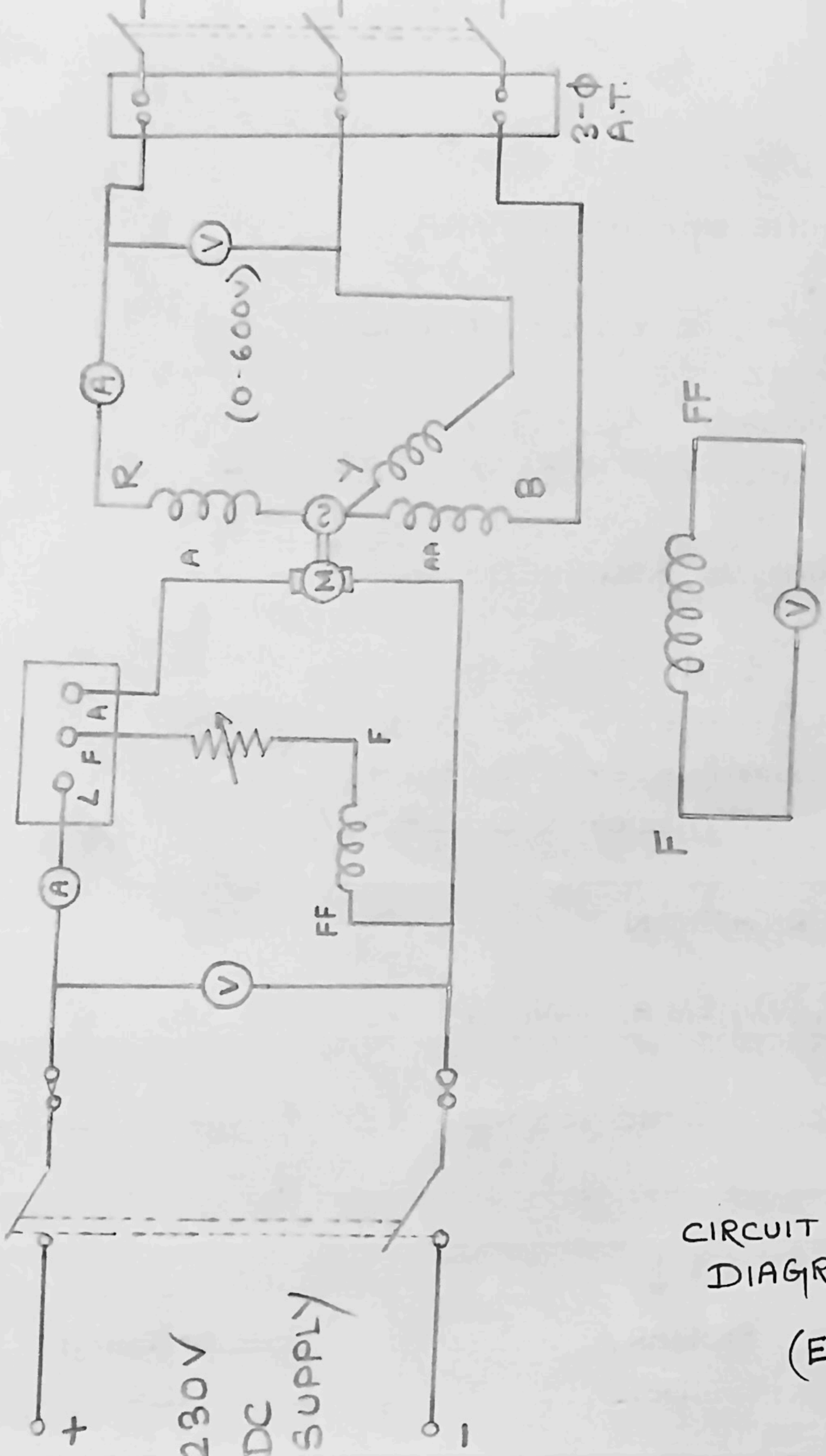
Two, 1-Φ Transformer
AC Ammeter (0-5 A)
AC Ammeter (0-30 A)
AC Voltmeter (0-250 V)

OBSERVATION

SL	V_1 (V)	I_1 (A)	W_1 (W)	V_2 (V)	I_2 (A)	ω_2 (W)
1.	220	0.95	55 × 2	12	48	25 × 2

PRIMARY SIDE

SECONDARY SIDE



CIRCUIT DIAGRAM (E/10)

Experiment-10

NAME - Slip test of a synchronous machine.

AIM - To determine X_d & X_q of a synchronous machine & draw the phasor diagram for 0.8 pf lagging.

THEORY - The slip test is a simple no-load test which is used to determine the direct-axis & quadrature axis synchronous reactance of a salient-pole synchronous machine.

X_d = maximum value of armature voltage per phase / minimum value of armature current per phase

X_q = Minimum value of armature voltage per phase / maximum value of armature current per phase.

PROCEDURE - Set the 3-phase variac output to zero switch position. Turn on DC supply. With minimum reactance & resistance in the field circuit start the DC motor.

SL	SPEED RPM	Armature V/phase		Armature C/phase	
		Maximum	Minimum	Maximum	Minimum
1.	1530	$131\sqrt{3}$	$129\sqrt{3}$	2.4	2.1

OBSERVATION TABLE :

Apparatus Required-

AC Ammeter (0-7.5 A)
DC Voltmeter (0-500 V)
AC Voltmeter (0-300 V)
Double Barrel Rheostat
Tachometer
Phase Sequence Motor
3-ϕ Variac

Expt. No.

Adjust field rheostat for synchronous speed. Increase alternator field current to generate rated voltage. Switch ON 3-ϕ AC supply. Check for phase polarity. Then remove the alternator field excitation & connect the UVW terminals of alternator to RYB of variac. Then start DC motor & bring it to near synchronous speed. Increase AC voltage to armature from variac.

CALCULATIONS-

$X_d = 131\sqrt{3}/2.1$
$= 36.01\,\Omega$

since :

X_d = maximum value of armature voltage per phase / minimum value of armature current/phase.

X_q = minimum value of armature voltage per phase / maximum value of armature current per phase.

So $X_q = 129\sqrt{3}/2.4$
$= 31.033\,\Omega$

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Teacher's Signature ....